6. High R&D intensity without high tech products: a Swedish paradox?

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INTRODUCTION

This chapter argues that a paradox is visible in the Swedish economy. The paradox has to do with the fact that while, on the one hand, a high proportion of the Gross Domestic Product (GDP) is spent on formal research and development (R&D), on the other hand, the Swedish economy produces only a below average percentage of R&D-intensive products relative to total manufacturing, compared to the average for the OECD countries. There thus seem to be problems in translating R&D results into R&D-intensive products, having to do, we argue, with specific Swedish factors at the firm and national levels.

Formal R&D is considered an indicator of input into knowledge creation and technical development and is therefore seen to be an indicator of innovativeness. There are therefore important reasons why such a paradox is a problem for Sweden and for other countries facing a similar situation. One reason is that both the old growth account literature and the modern economics of innovation identify knowledge and innovation as the main sources of productivity growth. The relative level of knowledge and technology embodied in industrial products therefore matters for a country's economic growth.

Although R&D can be used for many different types of low, medium and high tech products as well as for more basic research, Sweden is an interesting case because many have perceived it as a medium to high tech country. At least up until the early 1990s, Sweden was generally perceived as a successful economy, finding a successful, middle road of welfare capitalism. Moreover, Sweden has often been heralded as 'high tech' due to, for example, innovative ways of organizing manufacturing, extensive use of advanced production machinery, and a high percentage of GDP spent on R&D. In fact, research has shown that Swedish industry does use advanced production technologies extensively, for example in the engineering industry, which accounts for about half of manufacturing (Edquist and Jacobsson 1988).

Products are another matter. The specialized industrial structure of Sweden has been heavily based on 'refined' natural resources like paper and pulp, mining and engineering (Edquist and Lundvall, 1993). These are not high tech products, but Sweden has nevertheless had an aura of a medium to high tech country.

Sweden as a whole and particularly Swedish firms devote considerable resources to R&D. As a whole in the late 1980s, Sweden spent approximately 2.8 per cent of GDP on R&D, which is on par with the leaders such as Japan and the USA; many other small countries tend to invest a lower percentage (SIND, 1990a). Firms spend the majority (68 per cent) of this total R&D. Swedish industrial R&D is clearly dominated by a few large, multinational firms.

In this chapter, we analyse the performance of the Swedish economy in relation to the OECD average for R&D-intensive production relative to manufacturing as a whole. The figures are presented in the Appendix along with those for the performance of Germany, Japan, the Netherlands and the United States. The cross-country comparisons for each R&D-intensive sector show the proportion of R&D-intensive products in manufacturing compared to the OECD average. Our comments are, however, mainly restricted to explaining the apparent paradox in the Swedish economy.

This analysis is novel in two ways. Firstly, we specifically distinguish between use of high tech in production processes and its incorporation as R&D-intensive products. As argued below, the OECD definition of high tech products is used in order to enable international comparisons. Secondly, most comparative analyses of countries' competitive performance, such as Michael Porter's (1990) work, analyse exports. We analyse production within the country rather than exports. This approach is based on theoretical work in the economics of technical change which argues that it is production and development of technologies which lead to significant long-term positive externalities such as cumulative development of knowledge. Export data only imperfectly reflect this.

THEORETICAL CONSIDERATIONS

The fact that countries specialize in production and then trade different goods and services comes as no surprise to economists. In fact, classical and neoclassical international trade theorists have long stressed that differences between countries in terms of relative prices, availability of resources (land, labour) and market structures explain countries' specialization. Countries produce different goods, whereupon they trade internationally those where they have an advantage. However, in these theoretical constructions, particularly neoclassical theory, technology is an exogenous variable.[1] According to this logic, it makes no difference whether a country is specialized in low, medium or high tech goods, as long as they participate in international trade. Everyone benefits anyway.

In contrast, contemporary research on the economics of technical change starts from different assumptions and comes to different conclusions. Based on evolutionary economic theory, firms are assumed to differ in their knowledge about, and use of, various resources including knowledge and technology.[2] Firms are seen to have varying capabilities to develop, monitor and use technology and knowledge. They do not know which techniques are most efficient. Instead, they must invest in search, R&D or innovation processes to discover which technical alternatives are (potentially) possible in order to develop and choose among alternatives.

In the economics of technical change tradition, technology is endogenously generated within the economy rather than an external factor. Firms are the ones who often develop technologies of relevance for economic activities, sometimes in interactions with other organizations such as universities. The development and diffusion of technology is often local, tacit and cumulative within individuals, firms and countries (Dosi, 1988).

These assumptions about technology and knowledge in the economics of technical change have significant implications for analysing patterns of national production specialization and for linking high tech to economic growth and to productivity growth. Firms, and hence countries, have differing abilities to find and translate technology and knowledge into economic innovations, in the sense of new or improved products and production processes. In particular, Dosi, Pavitt and Soete (1990) conclude that whether or not firms in a specific country will be able to innovate, and in which industrial sectors, depends on initial conditions in firms, the organization of markets, and technological capabilities as well as on institutions affecting actors' capabilities and decisions about these conditions. Related research on 'national systems of innovation' has similarly indicated significant differences among countries in terms of ability to innovate and in terms of institutions and organizations.[3]

Because the economics of technical change perspective emphasizes a dynamic view of the economy, technical change is assumed to modify the economic playing rules by creating more efficient processes and more attractive products. Innovation, rather than price differences, is central. Therefore, if a country is specialized in technologies/sectors with higher opportunities to innovate, its longer-term economic prospects are better than those of countries specialized in less innovative sectors. It matters whether a country produces bulk goods competing on price or specialized products competing on quality, uniqueness or other qualities which enable temporary monopoly rents. In the latter case, countries have a better probability of achieving productivity growth and hence economic growth.

Although the specialization of production is only one of many factors influencing labour productivity, we argue that the relative percentage of R&D-intensive goods in industrial production can be linked to productivity growth. The reason is that labour productivity is an indicator, which measures efficiency of the manufacturing process in price terms. Productivity and productivity growth indicate a ratio between value added (or sales) and employees (or number of hours worked). Thus, productivity can increase because the production process has become technically more efficient (and requires less labour) and/or because an improved/new final product can be sold at a higher price.

There are two theoretical reasons as to why these propositions about a relationship between productivity and R&D-intensive goods are important when analysing Sweden's (or other countries') production specialization.

The first is that if technological competence and capability do build cumulatively in an economy in interactions between firms and organizations, then a country which is relatively low tech will tend to stay so, and vice versa. Countries will tend to develop along specific 'trajectories' or paths of industrial specialization and technological competencies.

Secondly, if production of high tech products tends to create more positive externalities in an economy compared to low tech products, then countries specialized in high tech will tend to be in a better position to capture future returns arising from the dynamic creation of resources and rents (Tyson, 1992). In contrast, countries which lose a high tech specialization of production should be worried about the future economic health of their economy. Our analysis of the apparent Swedish paradox is based on these theoretical arguments.

CONCEPTUAL SPECIFICATIONS

Analysis of the level of R&D-intensive goods in Sweden and other countries requires international comparisons. A first question, then, is what constitutes an R&D-intensive good and industrial sector? It has already been argued that industrial R&D indicates the amount of resources devoted to technological innovation. R&D expenditures are resources spent on formal search activities. Other types of learning such as interactive learning within and between firms and development of tacit knowledge are usually not included in such figures. R&D expenditures have therefore been criticized as an inadequate measure of innovation. They are, however, still a useful measure partly because R&D expenditures do indicate intent to innovate and partly because international, comparative statistics are available.

Our study discusses the R&D intensity of industrial sectors. In turn, R&D intensity is often taken as an indicator of 'high, medium and low technology'. In a first classification, the OECD defined high tech industries as those which on average spend 4 per cent or more of sales value on R&D. Those industries which spend between 1 per cent and 4 per cent are medium tech and those spending less than 1 per cent are low tech.[4] This classification is used here.

The OECD criteria can then be used to identify industrial sectors as used in statistical databases. The ISIC (International Standard Industrial Classification) system uses three-digit numbers to denote broad industrial sectors. These three-digit categories in turn consist of several four-digit industrial product groups. According to the OECD's criteria, the following sectors/product groups were high tech in the ISIC, revision 2:

ISIC 3522	Drugs and Medicine
ISIC 3825	Office Machinery and Computers
ISIC 383	Electrical Machinery and Components[5]
ISIC 3845	Aerospace
ISIC 385	Technological Goods (Scientific Instruments)

These ISIC categories constitute the industries defined as R&D-intensive (high tech) in this chapter.

The OECD definition categorizes industries which can be seen to be, on average, high, medium or low tech across the eleven largest OECD economies. The purpose of taking an international average is that the categories can then be used to make comparisons among countries. Here we use these international categories to compare individual countries, especially Sweden, to the OECD average. However, because the categories are internationally determined, the percentage spent on R&D in each sector may or may not hold for each individual country. Thus, international comparisons can be made using the OECD classification, but individual deviations – in this case for Sweden – should be pointed out.[6]

These five industrial sectors thus consist of groups of products. As mentioned, we have made a conceptual distinction between technology used as process technology and the products which the industrial sector manufactures. Product technologies means what is produced and sold. Process technologies are used to make goods and services. It is a question of how things are manufactured. Only product technologies are analysed here.[7]

The importance of producing improved or new products goes beyond the price competition of equilibrium analysis. In a situation of dynamic Schumpeterian competition, the innovating firm can capture temporary monopoly rents for new and improved products. This gives firms incentives to innovate. In a dynamic sector – and hence in a dynamic economy – new and improved products are more important as a means of competition than price reductions (resulting, for example, from improved process technologies).

However, used alone, R&D expenditures say nothing about the efficacy of the innovation process nor about the level of technology used in production. For example, Pavitt has shown that in some capital-intensive, large-scale industries such as paper and pulp, where the process technology is advanced, the process technology is developed by upstream machine producers because they are better able to capture the economic benefits than the paper mills (Pavitt, 1984). Assuming that the paper and pulp industry does not invest much in R&D to develop their final products, the products sold by the machine producers would be more R&D-intensive than the products sold by the paper and pulp industry. In this example, the machinery is defined as a product technology when designed and sold by machinery makers, but it is a process technology when used by paper and pulp manufacturers.

Finally, we would like to point out that our analysis of the relative level of technology in products is preliminary. We have taken R&D intensity as a proxy for innovative effort, even though technology is also developed in other ways. We have taken R&D-intensive industries as a proxy for high tech products, even though there are discrepancies between products and industrial sectors; there are high tech products in low tech sectors and vice versa. Nevertheless, we have presented arguments as to why these are reasonable indicators.

THE SWEDISH CASE IN AN INTERNATIONAL COMPARISON

Trends in the R&D-intensive industrial sectors in Sweden during the past twenty years are here compared with the OECD average and with four other countries, namely Germany, Japan, the Netherlands and the United States. These comparisons can be found in the Appendix, which includes six figures. Figure 6.1 compares the Swedish share of R&D-intensive goods in production and in exports relative to the OECD average. Figures 6.2 to 6.6 illustrate developments in the five countries for each R&D-intensive sector listed above.

The Appendix to this chapter also contains a description of the STAN database – which is the source of the figures – and the equation used. Our comments will be restricted to Sweden but the reader should particularly note developments in Japan which has increased its specialization in the high tech product groups.

Figure 6.1 shows the Swedish share of exports and production of R&D-intensive products in manufacturing as a percentage of the OECD average from 1970 to 1990. The percentage of R&D-intensive goods in Swedish *exports* rose from the early 1970s to 1978, thereafter decreased, and then rose again at the end of the 1980s. Figure 6.1 also gives information about the relative specialization of Sweden in *production* of R&D-intensive sectors. Whereas exports showed an increase for several years at the end of the 1980s, the increase in relative production was minor. At the aggregate level of all R&D-intensive goods as a percentage of manufacturing, the Swedish percentage was at 71 per cent in 1990 (see Figure 6.1). In that this is well below 100 per cent, Sweden is not specialized in production of high tech products, relative to other industrialized countries. In fact, the general trend is that Swedish industry has become decreasingly specialized since 1975.

Figures 6.2 to 6.6 show each country's production as a percentage of the OECD average in the various R&D-intensive sectors. From the mid 1970s, the Swedish trend has been negative for three of the five R&D industrial sectors, namely, Office Machinery and Computers (ISIC 3825), Electrical Machinery and Components (ISIC 383), and Aerospace (ISIC 3845).[8] For these three sectors, Sweden was above, just at or just below the OECD average during the early to mid 1970s but subsequently became less specialized. Sweden's share of Technological Goods (ISIC 385) has been around 50 to 70 per cent of the average during the period but ended in a positive direction. By the early 1990s, Sweden was thus not specialized in any of these four high tech sectors.

There is, however, one exception to this generally negative Swedish trend, namely Drugs and Medicine (ISIC 3522). Sweden has gone from well below the OECD average in 1970 (44 per cent) up to and above the OECD average (104 per cent) in 1990 and has thus become specialized. This new area of specialization differs significantly from Sweden's previous specialization in the engineering and paper and pulp industries. A very interesting question demanding further research is therefore why and how Sweden has managed to specialize in Drugs and Medicine during this period.

In the other R&D-intensive industries which lie nearer Sweden's traditional specialization, Sweden has increasingly been left behind, relative to other industrialized countries. The empirical material presented in the Appendix thus indicates that despite large investments in R&D, the Swedish industrial structure has not been successfully (re)oriented towards R&D-intensive sectors during the past twenty years.

In order to argue that Sweden's relatively low and decreasing proportion of R&D-intensive goods in production, compared to the OECD average, affects economic growth and productivity growth, it is necessary to present some additional data. This data should preliminarily indicate whether or not a relationship between growth and productivity on one hand and R&D-intensive products on the other can be identified.[9]

One indicator of dynamic competition is whether the markets for high tech products have been growing equally as fast, faster or slower than for manufacturing as a whole. If the markets are growing faster, then this indicates that firms which successfully compete in these markets can expand production, thereby potentially stimulating growth and employment. For the period 1974–88 both in Sweden and in the OECD as a whole, market growth for each of the five R&D-intensive products was greater than for manufacturing as a whole.[10] In fact, the market which grew the fastest, Office Machinery and Computers (ISIC 3825), was the industrial sector in which Sweden most dramatically lost its position (see Figure 6.3). Japan dramatically increased its specialization in this sector from the early 1980s. A growing market indicates new market opportunities, which seem to be related to technical opportunities.

A study done by the Swedish Industrial Board (SIND, 1990b) about the dynamism of high tech firms corresponds to expectations that dynamic competition and growing markets rely on firms performing R&D.[11] SIND classified Swedish firms as high, medium and low tech based on R&D intensity. Although there are some exceptions, the SIND study generally indicates that large investments in R&D by firms led to a (much larger) growth in volume of production, as measured by increase in value added. This relationship between R&D and growth in value added is explainable if one assumes that R&D leads to new or modified products, for which market growth is rapid and which command a higher price in a situation of dynamic competition. Similar relationships held for the relationship between R&D and (absolute) productivity in the SIND study.

The relationship between R&D and productivity growth which showed up at the individual firm level in Sweden is generally supported at the industrial sector level for 1974–88. In a previous paper, we showed that in general in Sweden, productivity growth in R&D-intensive sectors was higher than for manufacturing as a whole (Edquist and McKelvey 1992, Chapter 4).[12] This was the general trend, although there were some exceptions.

Sweden seems to get, however, a decent return from its R&D investments, as indicated by some output measures. For example, Pavitt and Patel indicate that the number of patents per capita that Sweden takes in the USA is on par with those large countries which are innovation leaders (Pavitt and Patel, 1988; Edquist and McKelvey, 1992).[13] Sweden also has a positive technology trade balance, a figure which includes expenditures for patents, licenses, royalties, and know-how. In 1987, Sweden had a net positive balance of 562 million SEK and in 1989, a net positive balance of 821 million SEK (SCB, 1991). These sketchy output measures thus indicate that R&D investments in Sweden do lead to novelties valuable in that they can be protected as patents and/or sold as knowledge, know-how, etc. Of the R&D which is performed in Sweden, Swedish firms do seem to reap benefits, as indicated by innovation indicators. They do not, however, seem to have translated that knowledge into R&D-intensive products.

The question remains, to what extent is the Swedish phenomenon a paradox? Should we have expected that a high intensity of R&D results leads to the production of R&D-intensive products? It is a paradox if R&D is taken straight off the bat as an indication of innovativeness. The paradox may, however, be mostly apparent. In particular, R&D is an input measure of intent to innovate; an attempt to create something new. It says nothing about how efficiently those resources are used in the R&D process nor about whether the knowledge and technologies being developed are likely to be attractive on a market. We may be dealing with an apparent paradox, caused by an over-reliance on R&D indicators in the economics of technical change tradition.

There are two sides of the paradox, the high R&D intensity and the low specialization in R&D-intensive products. Specialization has already been discussed at length and we will return to it in our concluding remarks. Let us therefore focus on some characteristics of the former side. Part of the paradox may be explained by the orientation and efficiency of the R&D performed within Sweden. Firstly, one might imagine that the high percentage of GDP spent on R&D reflects government spending on basic research. However, this hypothesis does not hold, as firms perform 68 per cent of the gross expenditures on R&D (OECD, 1993). Of the total industrial R&D, the majority goes to product innovations.

Another reason may be the relatively high R&D intensity of Swedish industrial sectors which are internationally considered medium tech industries. Two sectors in particular seem to pass the criterion. The medium tech sector Engineering (ISIC 382) minus the high tech sector Office Machinery and Computers (ISIC 3825) spent 5.8 per cent of sales on R&D in 1987 and 4.1 per cent in 1991. Transport Equipment (ISIC 384) also spent significant amounts on R&D. This category includes both aerospace (high tech) and automobiles (medium tech). Swedish industrial statistics do not provide separate R&D statistics for the aerospace and automobile industries, but the broader Transport Equipment (ISIC 384) spent 6 per cent of sales on R&D in 1987.[14] Because of the firms' mix of products, it is thus not clear whether the Swedish automobile industry alone – without aerospace – would be high or medium tech, although another analysis of Sweden (NUTEK, 1995, p. 28) has placed automobiles as high tech. Even very low tech sectors like Paper and Pulp Products may spend relatively more in Sweden on R&D as a percentage of sales than the OECD average.

A third reason for the high R&D intensity has to do with the Swedish structure of production. Both production and R&D expenditures are heavily dominated by large, multinational firms. Between ten and fifteen firms account for over 50 per cent of industrial R&D, and firms with more than 1000 employees account for almost 80 per cent of the total industrial R&D.

Swedish firms have tended to keep a large percentage of their total R&D – up to 70–80 per cent – within Sweden while placing production abroad. In other words, if their R&D investments were spread out over the world production activities of these Swedish multinational firms, then their R&D intensity would be lower. The level of R&D in Sweden may thus reflect the Swedish economy's reliance on large engineering firms placing production abroad – rather than on Sweden's unusually high innovative opportunities in medium tech sectors. Firms have thus, in some sense, made Sweden a knowledge producer without domestically translating that knowledge into economic value. However, these large firms have recently increasingly moved R&D abroad, thereby opening the possibility of a changing situation in the future (Cantwell, 1994; Håkanson and Nobel, 1993). This is reflected in the fact that 1987 was a peak for investment in industrial R&D as a percentage of sales in Sweden, after which it has dropped.

Although these various factors explain part of the apparent Swedish paradox of high R&D intensity without high tech products, it is still troubling that Sweden has mostly either remained de-specialized or lost specialization in the high tech products during the past twenty years. There seem to be particular Swedish circumstances which, by contributing to the problem, create a political/economic situation in which this paradox could arise.

CONCLUDING REMARKS

The apparent paradox of high R&D intensity without specialization in R&D-intensive products in Sweden is a phenomenon requiring additional explanation and discussion. The reasons why Sweden has become increasingly de-specialized in production of R&D-intensive products, with the notable exception of Drugs and Medicine, include both firm-specific and national contextual factors, such as political and institutional factors.

As mentioned, both Sweden's production structure and Sweden's industrial R&D infrastructure are heavily dominated by large firms. These firms account for the majority of industrial R&D, and their decisions to invest, or not invest, in new products and sectors strongly affect the Swedish industrial structure. Small Swedish firms have not been able to exploit R&D-intensive products and grow rapidly into larger firms to an extent similar to that in the USA. Nor have large firms diversified as in Japan.[15] Although there are some notable exceptions, it seems that these existing, large Swedish firms stick close to existing products when innovating and producing.

According to David Teece (1988), this is rational behaviour because a firm's 'core business' is mutually dependent on its knowledge base. Because of the cumulative knowledge base and firms' existing complementary assets, such as marketing, those new products which firms choose to take to market will tend to be close to their previously successful products. If, due to national contextual factors, Swedish firms continue to be profitable by producing old prodncts, then this results in a lack of structural change, which is in turn a partial explanation of why Sweden is below the OECD average in high tech products.

According to these ideas about firm behaviour, we should expect that Sweden as a whole should remain specialized in its traditional pattern of industrial production. As that specialization has tended to be fairly medium to low tech – paper and pulp, steel, mechanical engineering, etc. – it is not so surprising that Sweden is not currently specialized in high tech products. There are, however, reasons to be concerned about developments in Sweden, particularly since relative high tech specialization has decreased.

To understand why Swedish firms particularly lack incentives to change, national contextual factors which support and/or hinder innovation in Sweden must be included in our analysis. A full analysis of the various factors constituting the Swedish system of innovation cannot be presented here, but it is clear that the Swedish state has played a key – if unfortunate – role in reducing firms' incentives to innovate during the 20-year period studied here.

In particular, the Swedish state gave substantial economic support to ailing mature industries during the 1970s and early 1980s and devalued the Swedish crown several times from 1976 to 1982. Devaluations enabled existing firms to make substantial profits from mature products. In addition, financial speculation became common due to deregulated financial markets in the 1980s. These factors reduced the incentives to innovate. This seemed to keep the Swedish economy rolling for a while, but Sweden currently has very serious industrial structural, unemployment and government budget problems. This indicates that government policies which were intended to be immediate, apparent solutions turned out to help cause longer-term problems. The missing pressures in Sweden to innovate and to renew the industrial structure are therefore a partial explanation for the Swedish ailment.

The lack of incentives to exploit product innovations, which would have led to structural change, has contributed to the current economic crisis, which became apparent by 1991. Sweden shifted rapidly from being a model economy successfully balancing market pressures and supporting a welfare state to just another example of a national economy with deep problems. The Swedish crisis has included a rate of official unemployment (8–12 per cent) not seen since the Great Depression; a decrease in industrial output and industrial employment of about 20 per cent from 1989 to 1993; and a yearly government budget deficit at about 13 per cent of GDP.

Another depreciation of the Swedish crown has also occurred. Although the Swedish government and the Central Bank tried very hard in 1992 to defend the currency, the economic crisis and financial speculation forced them to abandon the fixed exchange rate. The floating crown promptly sunk, with a depreciation of about 20–25 per cent against the currencies of the major industrial countries. Depreciation has once again enabled a surge in exports and in profits of those large Swedish firms involved in exports, particularly of traditional products like paper and pulp.

This made traditional Swedish goods relatively less expensive abroad, and sales are not due to larger increases in efficiency and productivity relative to competing countries. Thus, the apparently positive trends of export growth and sky-rocketing profits in Sweden in 1994–95 are primarily based on the depreciation. Indeed, a major part of the rising capital investments in 1994 and 1995 have been going to traditional sectors like steel and forest-based industries. It has simply become more profitable to export the same old products, produced in the same old way. Once again, Sweden seems to be making another loop in the vicious circle of short-term solutions and short-term surges which aggravate the longer-term, structural problems.

The Swedish phenomena analysed here are interesting because, as we have argued, some technologies/sectors allow more opportunities to innovate than others. Innovations seem to be a vital, if partial, cause of productivity growth and economic growth. Therefore, from a perspective of the economics of technical change, a dynamic economy requires continuous reconstitution of products, firms and industries. If a country is specialized over time in sectors with high innovative opportunities, then its longer-term economic prospects are better than those of countries specialized in less innovative sectors. An economy which does not change falls behind. This is the basic reason why it matters in which industrial sectors countries are specialized.

APPENDIX

This chapter makes an international comparison of R&D-intensive manufacturing sectors from the early 1970s to the early 1990s. The comparison is between individual countries – Sweden in particular – and the OECD average. Such an analysis requires long-term, internationally compatible statistics. We therefore decided to use the OECD STAN (STructural ANalysis for industrial statistics) database. In STAN, data from the older OECD COMTAP (Compatible Trade and Production) database and other sources has been converted and estimated to be comparable across time and countries. We used the 1994 version.[16]

Our calculations are based on production in countries. In contrast, it is most common to use some index of export specialization to analyse countries' production specialization (Dalum, 1992; Porter, 1990). The most common one is the Basalla index. This chapter instead analyses the production structure, using a similar index. Our argument is that production offers the best indicator of potential positive externalities involved in developing commercially relevant technologies. Actual production ensures more positive externalities, both in the immediate and longer-term periods. Export specialization reflects production specialization only in an imperfect manner.

More specifically, the following figures compare the percentage of R&D products in countries' manufacturing as a percentage of the average of OECD countries. The basic formula is:

$$\frac{Y_{ij} / Y_m}{Y_{ijO} / Y_{mO}}$$

where

Y_{ij} is output, current prices, of R&D-intensive sector i in country j
Y_m is output, current prices, of total manufacturing in country j
Y_{iO} is output, current prices, of R&D-intensive sector i in the OECD
Y_{mO} is output, current prices, of R&D-intensive sector i in the OECD.

The OECD average is defined as 1.00, or 100 per cent. If a country is above the average (1.00), it is defined as specialized and if below the average, it is not specialized.

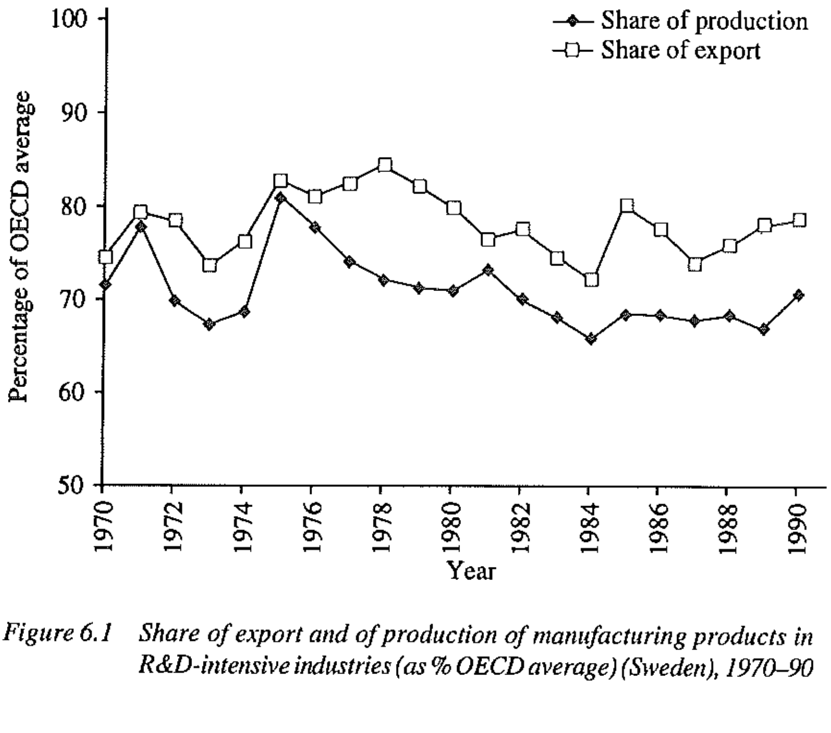

Figure 6.1 Share of export and of production of manufacturing products in R&D-intensive industries (as % OECD average) (Sweden), 1970–90

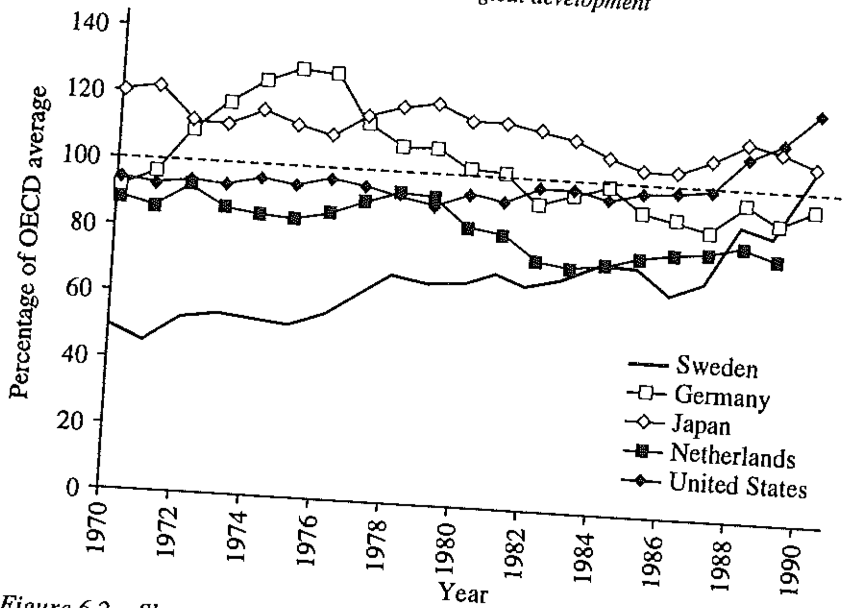

Figure 6.2 *Share of ISIC 3522 (Drugs and Medicine) of manufacturing production in five countries (as % OECD average), 1970–90*

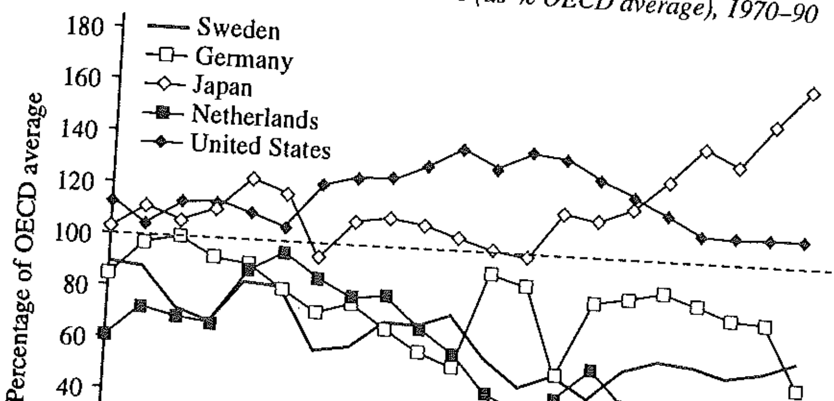

Figure 6.3 *Share of ISIC 3825 (Office Machinery and Computers) of manufacturing production in five countries (as % OECD average), 1970–90*

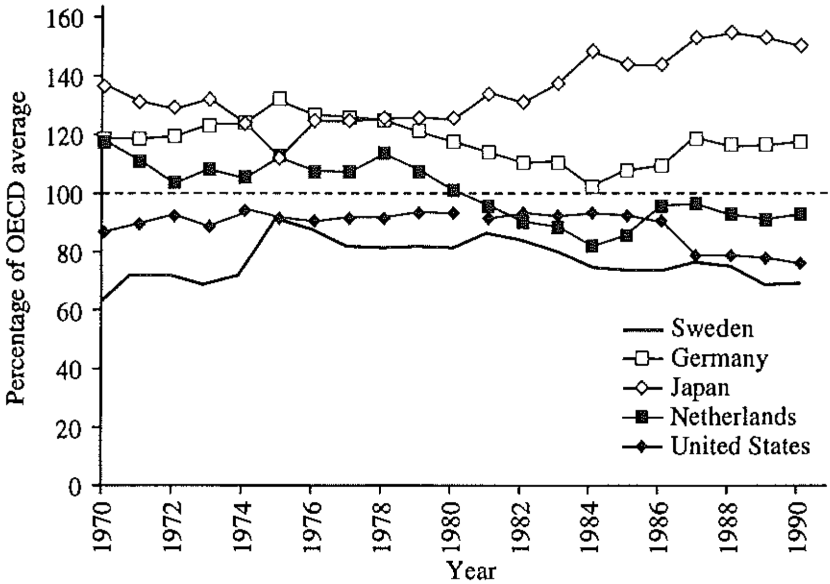

Figure 6.4 *Share of ISIC 383 (Electrical Machinery and Components) of manufacturing production in five countries (as % OECD average), 1970–90*

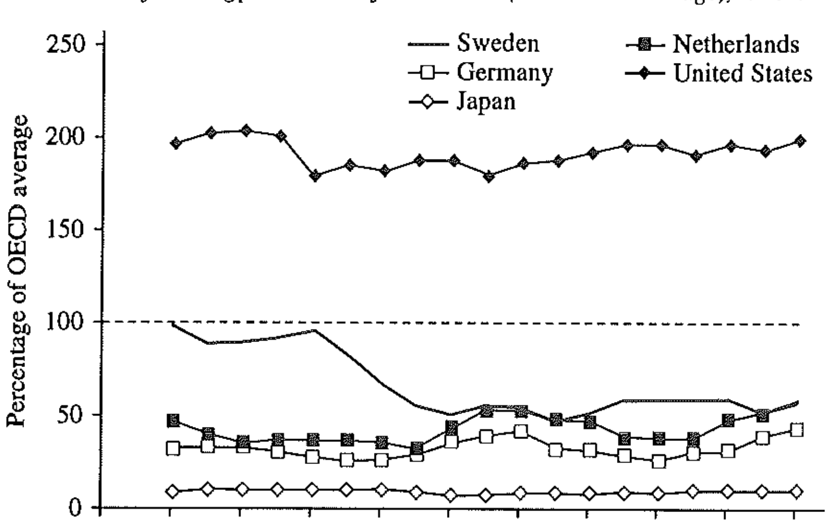

Figure 6.5 *Share of ISIC 3845 (Aerospace) of manufacturing production in five countries (as % OECD average), 1970–90*

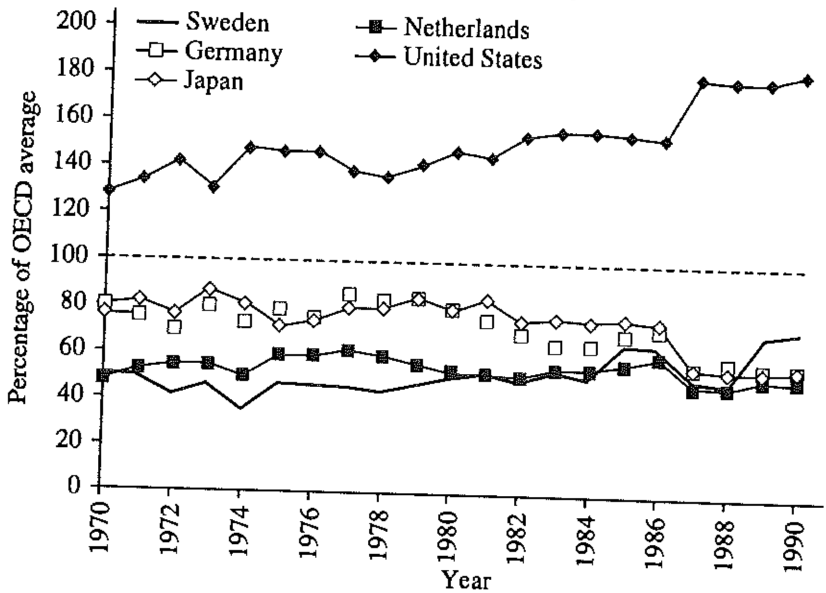

Figure 6.6 Share of ISIC 385 (Technological Goods) of manufacturing production in five countries (as % OECD average), 1970–90

NOTES

François Texier has given valuable help in updating the analysis and figures. We also received valuable comments at the EAEPE conference in Copenhagen in 1994. The data has not been revised since the original book submission in 1995. We would therefore like to point out that Sweden has increased production in telecommunications, which may affect the sector Electrical Machinery and Computers positively.

1. The new trade theories and the new growth theories also increasingly take technology into account. They have been criticized, however, for retaining an oversimplified view of technology and for sticking too closely to the general equilibrium analysis from which they were mutated (Dosi, Pavitt and Soete, 1990).
2. Nelson and Winter (1982) is the seminal work in this field.
3. Two influential books have recently been published on national systems of innovation, namely Lundvall (ed.) 1992 and Nelson (ed.) 1993. Edquist (1993) outlines various approaches to systems of innovation, including national, sectoral and regional ones. McKelvey (1991, 1994) critically analyses several approaches, whereas McKelvey (1993) analyses Japan in terms of institutions supporting innovative activities.
4. In 1994, the categories were revised and changed to four categories – high, medium-high, medium-low and low tech sectors (OECD, 1994, p. 231). In this classification, the high tech sectors only include those with more than 10 per cent of R&D expenditures/production.
5. ISIC 383 can be divided into three high tech product groups at the four-digit numbers ISIC 3831 (Electrical Industrial Machinery), ISIC 3832 (Radio, TV and Communication Equipment), and ISIC 3839 (Electrical Apparatus) and one lower tech product group ISIC 3833 (Household Appliances).

6. In Sweden between 1981 and 1991, the first four R&D-intensive industries listed above spent more than 4 per cent of sales value on R&D, as expected from the OECD definition of high tech. In the fifth sector, Technologial Goods, the main product is Scientific Instruments. During the 1970s and 1980s, the Swedish scientific instrument industry spent more than 4 per cent, but declined to 2.7 per cent in 1989 and further declined to 1.9 per cent in 1991. Thus during the twenty years analysed here, Scientific Instruments has fallen below the 4 per cent cut-off. (Based on SCB, 1983, 1985, 1989, 1991 and 1993.)
7. The making of new or improved products may or may not be closely dependent on process technology. The degree of dependence between product and process technologies can vary among different products and industrial branches.
8. For Electrical Machinery and Computers one explanation for the decline is that Sweden was specialized in electro-mechanical products in the 1970s but did not manage to make the transition to electronic products. Note, moreover, that Figure 6.5 indicates that the United States is extensively specialized in Aerospace, relative to the OECD average. This skews the distribution for the other countries.
9. Research on the relations between R&D and productivity includes numerous contributions, of which two notable ones include Bailey and Gordon (1988) and Nelson (1981).
10. See Edquist and McKelvey, 1992, Chapter 4. In that work, Table 17 shows that in both current and constant prices, all five of the R&D-intensive sectors had faster market growth in Sweden than for manufacturing as a whole. Table 18 shows that the annual growth rate in total OECD imports, current prices, was also higher for R&D-intensive goods than for manufacturing as a whole.
11. See also Edquist and McKelvey, 1992, Figure 3.14 and pp. 67–9. SIND uses the same classification as the rest of this chapter, but they classified *firms* as high to low tech whereas this chapter discusses industrial *sectors* as high to low tech.
12. Based on Swedish industrial statistics, we calculated productivity growth in Sweden for manufacturing as a whole and for each of the five R&D-intensive sectors for the periods 1974–80 and 1980–88. We calculated productivity in four ways: as sales value divided by number of employees (Tables 20 and 22) and as value added divided by number of employees (Tables 21 and 22). We calculated them in both current and constant prices. We would like to point out that the category 'manufacturing as a whole' includes the R&D-intensive sectors.
13. American patents can be considered an indicator of various countries' contribution to the global pool of knowledge.
14. According to the 1987 annual report, the Volvo group as a whole spent 5 per cent of sales on R&D and the Saab group spent 7.3 per cent of invoicing on R&D. However, both industry groups include products in the higher and medium tech segments of the transport industry. The Volvo group included automobiles, trucks, buses, motors for marine and industry, aircraft engines, food products and other. Saab included automobiles, trucks, buses, aerospace, advanced materials, automation and military and control engineering. Neither the firms' annual reports nor official statistics specify how R&D expenditures are distributed among product groups.
15. Analysis of USA based on Mowery and Rosenberg (1993) and of Japan on Goto and Odagiri (1993).
16. OECD, DSTI (STAN/Industrial) 1994. The countries included as the OECD average in STAN are Australia, Belgium, Canada, Denmark, Finland, France, Germany, Italy, Japan, Netherlands, Norway, Sweden, the United Kingdom and the United States.

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